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Technical Memorandum 78099

Fabrication of Light Guides for Astrophysics Experiments

Stuart E. Tull

APRIL 1978

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771



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**FABRICATION OF LIGHT GUIDES FOR
ASTROPHYSICS EXPERIMENTS**

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**GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland**

PREFACE

For the past ten years the Goddard Space Flight Center's Plating and Plastics Section of the Fabrication Engineering Branch has been engaged in the fabrication of isochronal and irregular shaped light guides. The light guides are fabricated for the Gamma Ray and Nuclear Emulsions Branch for utilization in high energy cosmic or gamma ray experiments. Fabrication procedures for producing suitable light guides were developed exclusively by personnel assigned to the Plating and Plastics Section.

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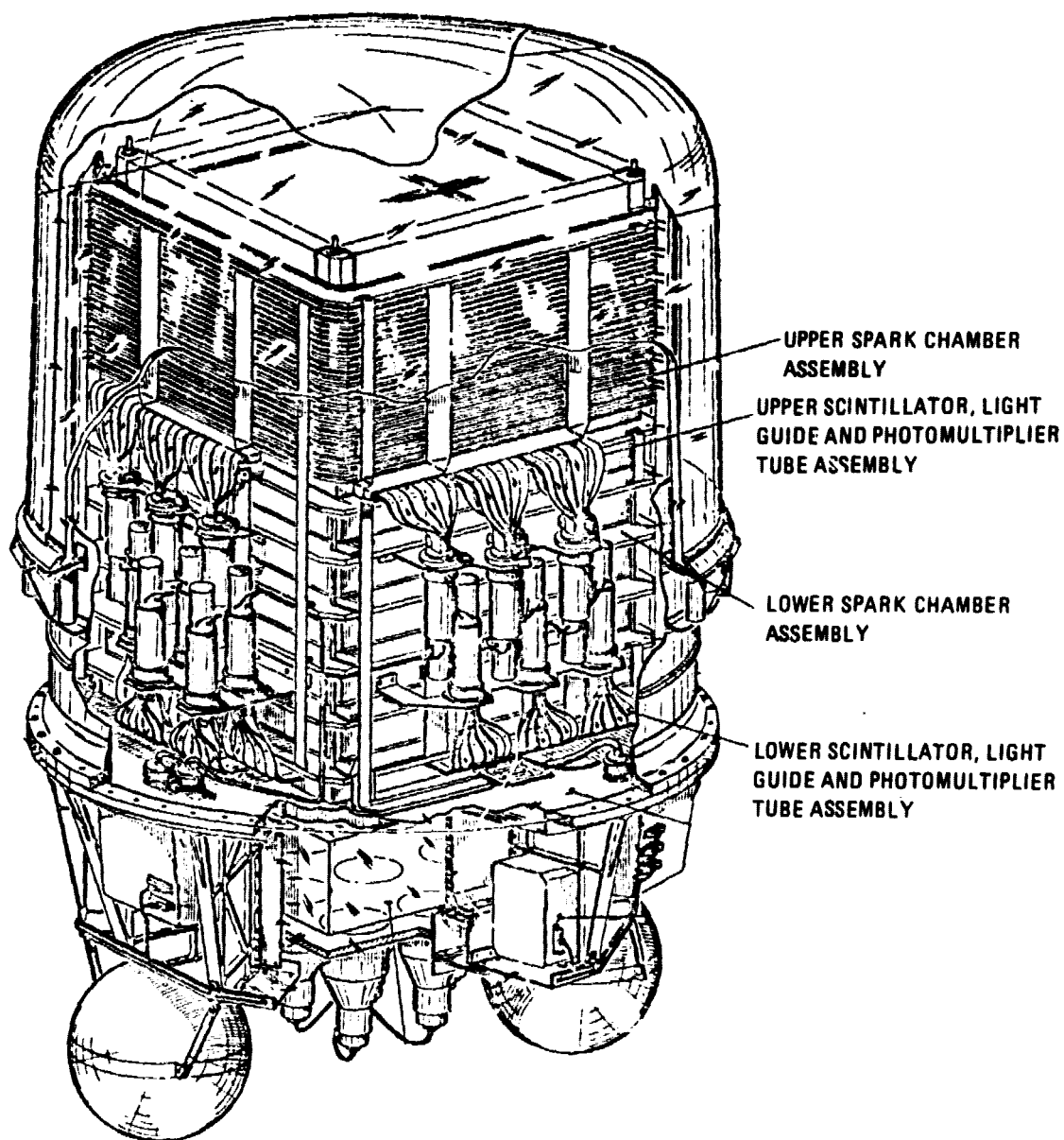
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Frontispiece. Light Guides Assembled in
Gamma Ray Experiment

INTRODUCTION

The purpose of light guides is to collect light emitted from a scintillator and lead it to a photo-multiplier tube where it is converted into an electrical signal. The light guides are fabricated from a series of rectangular strips of acrylic. Their geometry is formed such that the area at the edge of the scintillator is transferred into an area of equal dimension at the face of the photomultiplier tube. In some applications the strips must be of equal length in order for the light to take the same time interval to traverse each strip. This is necessary to avoid timing distortion. Since the light is transmitted by total internal reflection, the light guides must be fabricated from clear plastic. The surface of the plastic must be as smooth as possible, free of dirt, scratches or any other imperfections that could result in a reduction of the amount of light received at the photo-multiplier tube. The above factors are critically important since under optimum conditions only 3 percent of the light emitted in the scintillator can be expected to collect at the photo-multiplier tube. The remaining light is lost due to radiation.

Light guides are fabricated in three stages: (1) The preparation stage where the acrylic sheet material is sawed into strips, machined, and polished; (2) The forming stage when the acrylic strips are twisted into the proper geometric shape at an oven temperature of 140°C (284°F); and (3) The finishing stage when the bonding, final polishing, and cutting of the light guide to its specified length are performed.

SELECTION OF ACRYLIC MATERIAL

In the fabrication of light guides there are usually three types of acrylic cast sheet material preferred. Plexiglass-G¹ is considered the standard type used for applications that do not require special properties found in other more expensive types. Its properties are as follows:

1. Colorless and transparent material available in a variety of transparent and opaque colors.
2. When the material is heated to forming temperature, it shows a uniform shrinkage of approximately 2.2 percent in length and width and increases approximately 4 percent in thickness. Can be sawed, drilled, and machined like wood or soft metal.

¹Rohm Haas & Co.

3. As a thermal insulator (U-Factor), it is approximately 20 percent better than glass.

Each of the following specialty formulations is similar to Plexiglas-G, but differs slightly in certain characteristics. A comparison of their physical properties is described as follows.

Plexiglas II UVA

Plexiglas with ultra-violet absorbing properties in addition to the same mechanical properties as Plexiglas-G. The material is manufactured to more exacting standards of optical quality.

Plexiglas II UVT and IAUVT

Same mechanical properties as Plexiglas II UVA with increased transmittance of ultra-violet light in the wave lengths between 280 and 360 nanometers.

FABRICATION PROCEDURES

Preparation

1. Saw material into strips from acrylic sheet stock in accordance with drawing requirements. Provide sufficient length for a screw clamp at each end of the light guide with sufficient extra length at the base end for clamping the strips while forming light guide, figures 1 and 2.
2. Add support strips of a different thickness (for identification purposes) to each side of light guide to ensure that sharp corners on strips are maintained during machining and polishing operations.
3. Drill holes approximately 6.37 mm (0.25 inch) diameter for screw clamps as shown in photo 1.
4. Machine clamped strips to specified width, allowing 0.127 mm (0.005 inch) on each surface for sanding and polishing, photo 2.
5. Hand sand the machined surface with 400 or 600 grit silicon carbide paper (dry paper recommended), photo 3. The clamped light guide strip assembly may be lightly buffed on a clean wheel to highlight areas for sanding.

6. Hand polish with MGH-17¹ and MGH-16, or equal, to remove blemishes and microscopic scratches.

CAUTION

To avoid rounding off sharp corners, do not buff strips without side supports. Only highly polished edges with sharp corners, free of scratches and blemishes will satisfactorily contain and transmit light.

7. Disassemble clamped light guide strip assembly and discard the side support strips.
8. Clean light guide strips with warm water to remove dirt due to machining, buffing, and polishing.

CAUTION

To avoid scratching the plastic surface, do not wipe light guide strips with coarse cloth or paper.

9. Reassemble light guide using a thin Teflon² separator 0.025 to 0.762 mm (0.001 to 0.003 inch) between light guide strips in clamped areas, figure 2.

Forming

1. Heat assembled light guide to 140°C (284°F) in a suitable temperature chamber until the strips become pliable.
2. Using jigs, fixtures and templates, figures 3 and 4, form each strip to its specified configuration, photos 4, 5, and 6. This operation must be performed while the light guide assembly is in the temperature chamber.

NOTE

Reheat temperature chamber periodically to keep plastic strips pliable.

¹Meguiar's Mirror Glaze.

²Dupont, De Nemours and Co., Inc.

CAUTION

1. Light guide strips will blemish if allowed to touch each other while being formed in the temperature chamber.
2. Strips will blister if chamber is allowed to overheat.

Finishing

1. Disassemble light guide
2. Remove and discard Teflon separators
3. Hand polish with MGH-17 and MHG-16 (It may be necessary to remove minor blemishes by sanding).
4. After polishing, reassemble light guide with screw-type clamp in preparation for bonding.

Bonding

1. Layoff trim lines on both ends to proper length in accordance with drawing requirements.
2. Saw cut end opposite base (screw clamp) allowing sufficient length for final machining.
3. Bond the strip ends together, figure 5 and photo 7, using one or two drops of H94* Acrylic solvent or equivalent to produce a bonded area approximately 12.7mm (0.50 inch) long. Allow sufficient time for curing (approximately four hours).
4. Machine to final length at trim line, photo 8.
5. At base end trim line, bond strips together as in paragraph 3.
6. Clamp base end with C-clamp and use wood or plastic material for cushioning between the clamps and the acrylic strips.

*APCO, Inc.

7. Allow sufficient time for curing solvent (approximately four hours). Remove C-clamp and saw cut end allowing sufficient length for final machining. Machine to proper length per drawing specification, figure 5 and photo 9.

NOTE

1. Light guide ends need not be polished when bonded to the scintillator tile plate, photo 10.
 2. Polished ends must be provided for light guide assemblies which are not bonded to a scintillator tile and/or photomultiplier tube.
8. Refer to Photo 11 for typical Light Guide configurations.

CONCLUSION

This technical memorandum outlines the procedures which can be effectively utilized in the fabrication of light guide assemblies for astrophysics experiments. Development of these procedures in conjunction with high standards of workmanship has resulted in Goddard's Plating and Plastics Section becoming the primary source of supply. Since these assemblies are critical components of experiments for the measurement of high energy outer space radiation, their development has significantly contributed to the success of the Goddard mission. This technical memorandum is intended to assist Government and contractor personnel in the fabrication of light guide assemblies to standards suitable for astrophysics experiments.

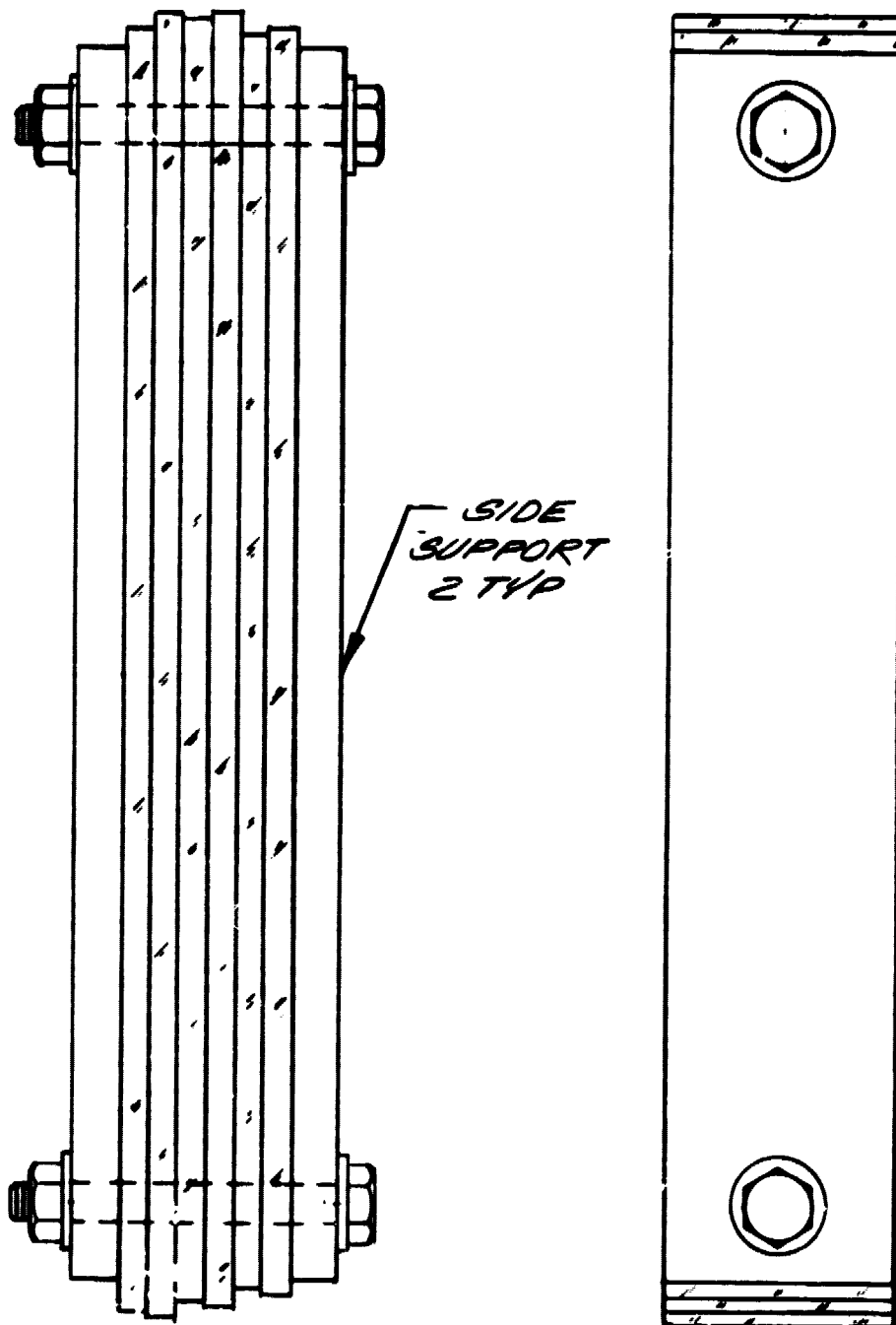


Figure 1. Strips Assembled with Side Supports and Screw Clamps

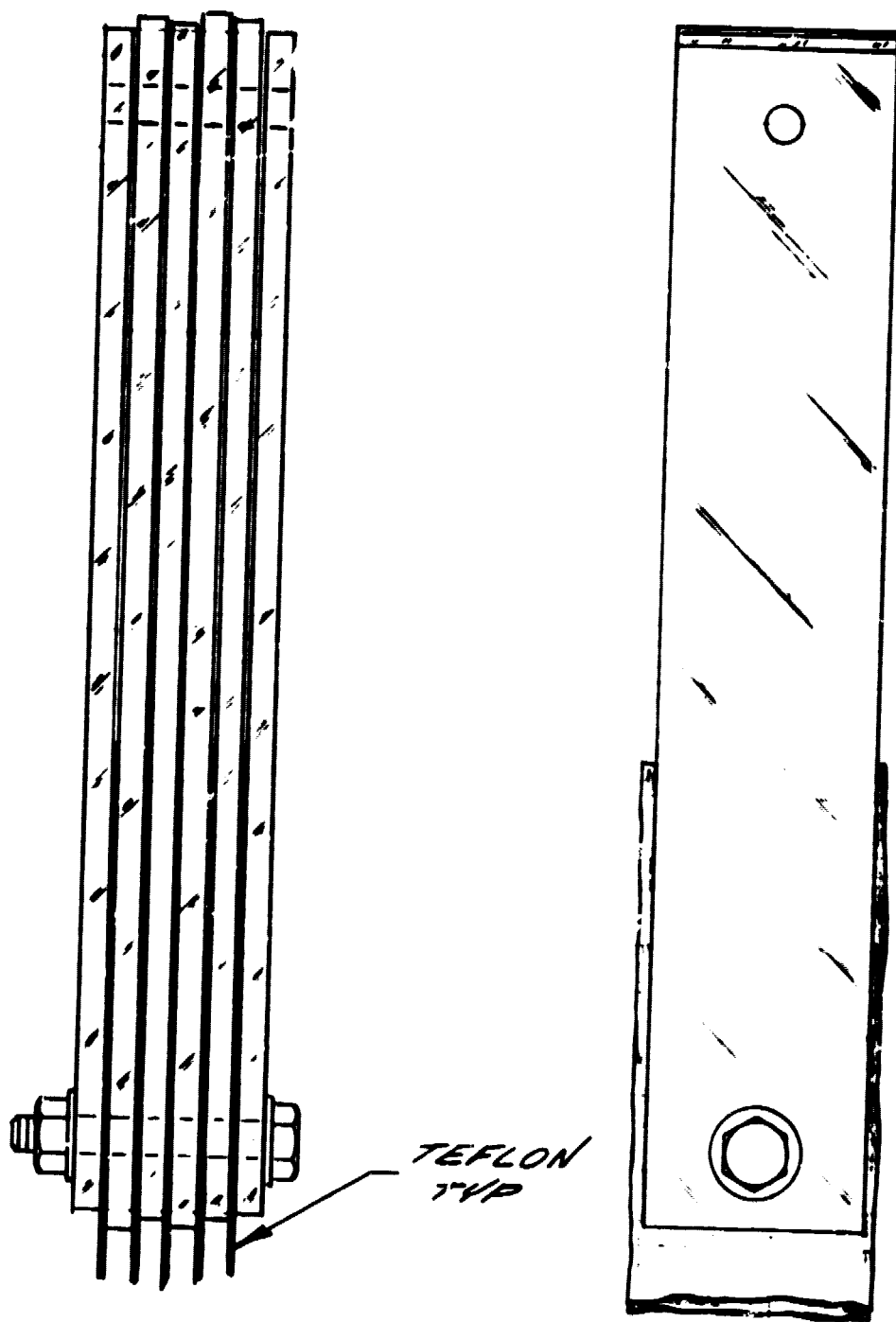


Figure 2. Strips and Separators Ready for Bending Fixture

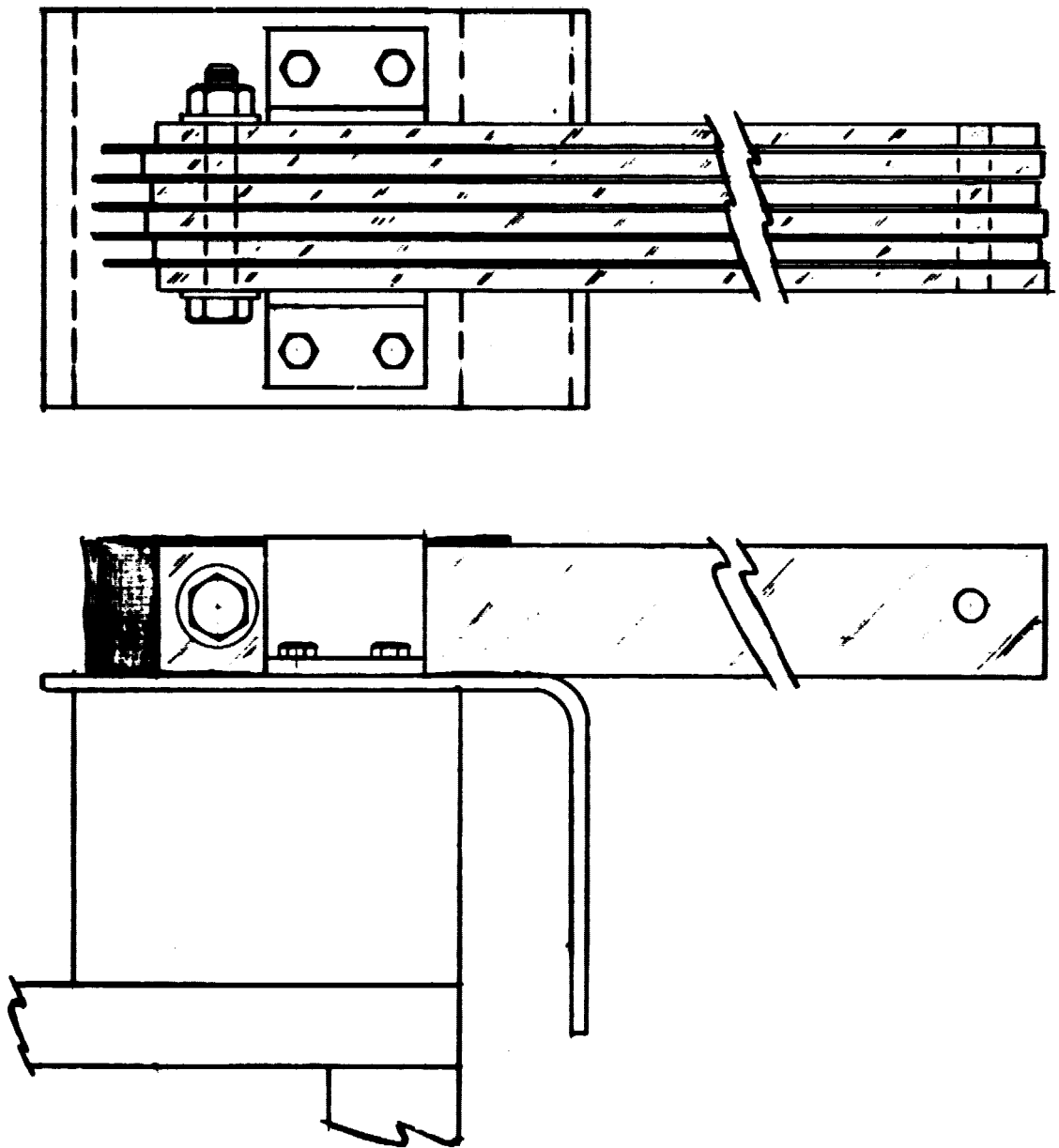


Figure 3. Strips on Bending Fixture to be Heat Formed

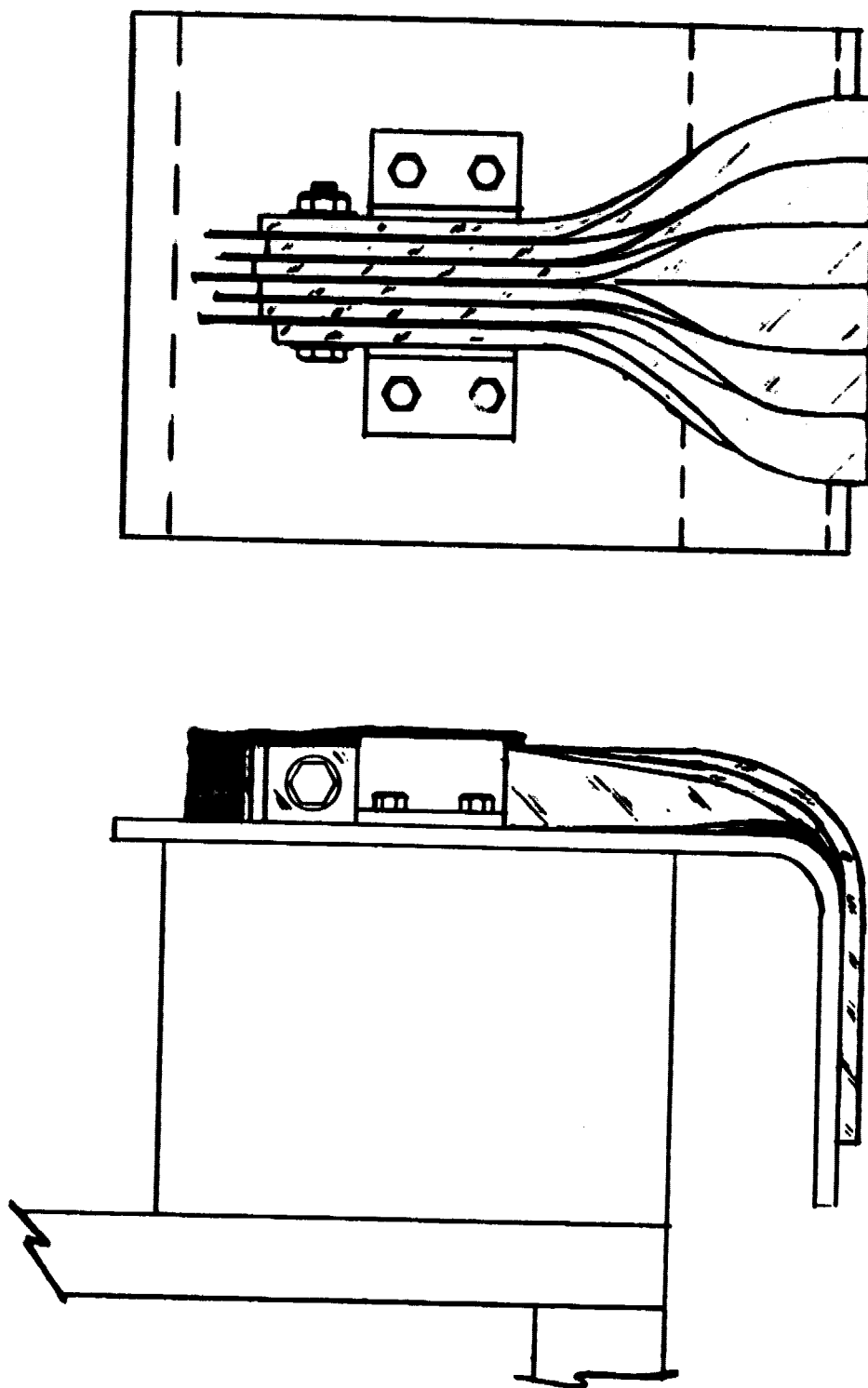


Figure 4. Strips Formed Into Light Guide

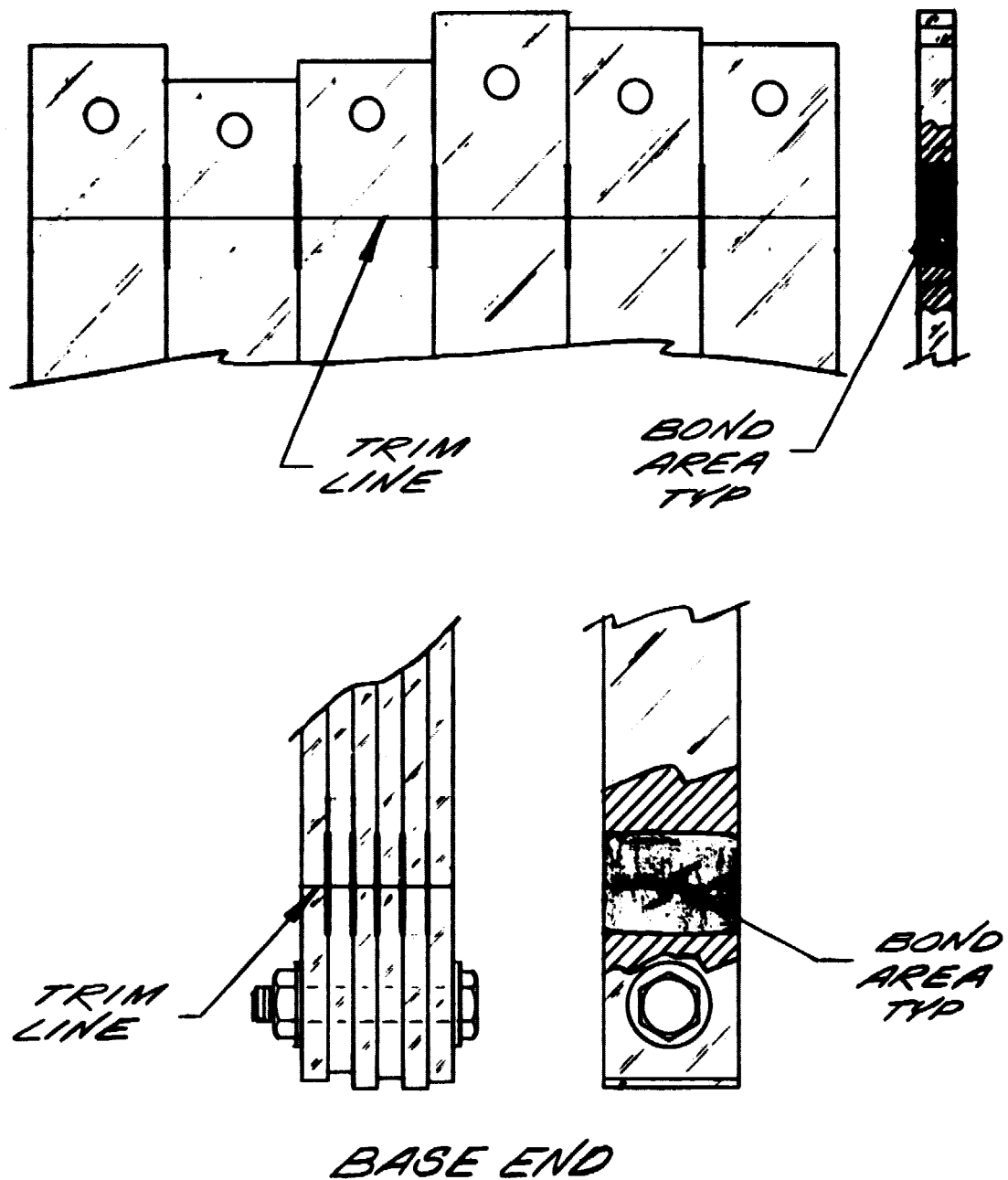


Figure 5. Light Guide Showing Layoff of Ends and Corresponding Bond Areas

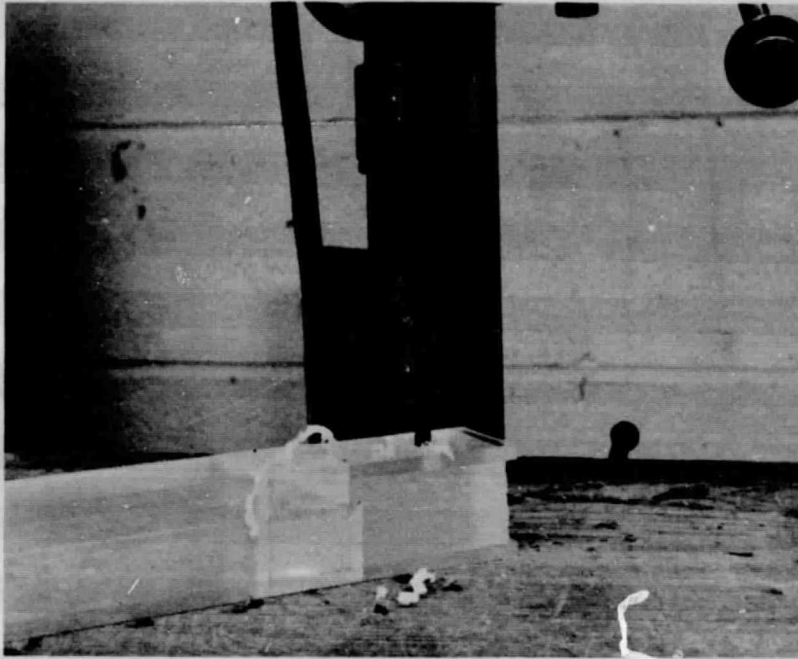


Photo 1. Drilling Holes for Screw Clamps

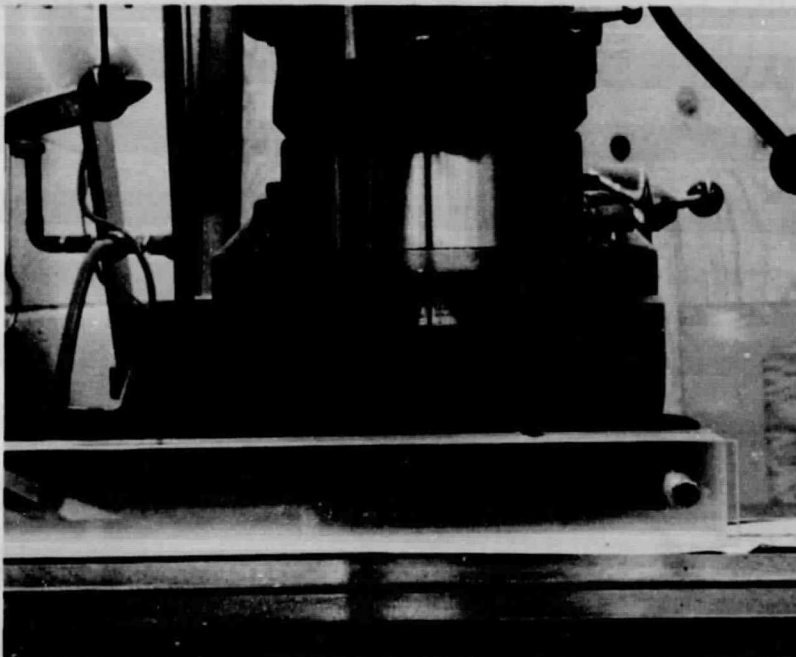


Photo 2. Machining Edges

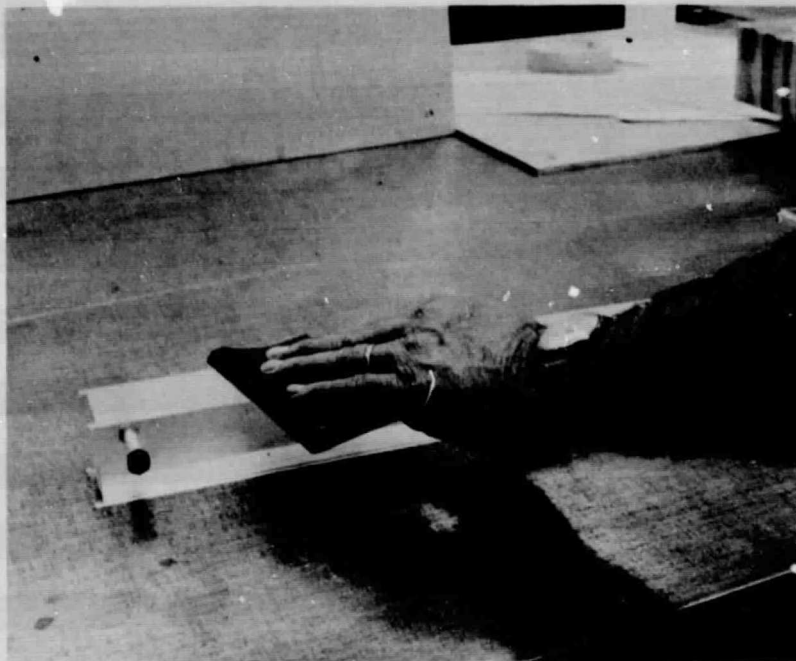


Photo 3. Sanding Edges Prior to Polishing

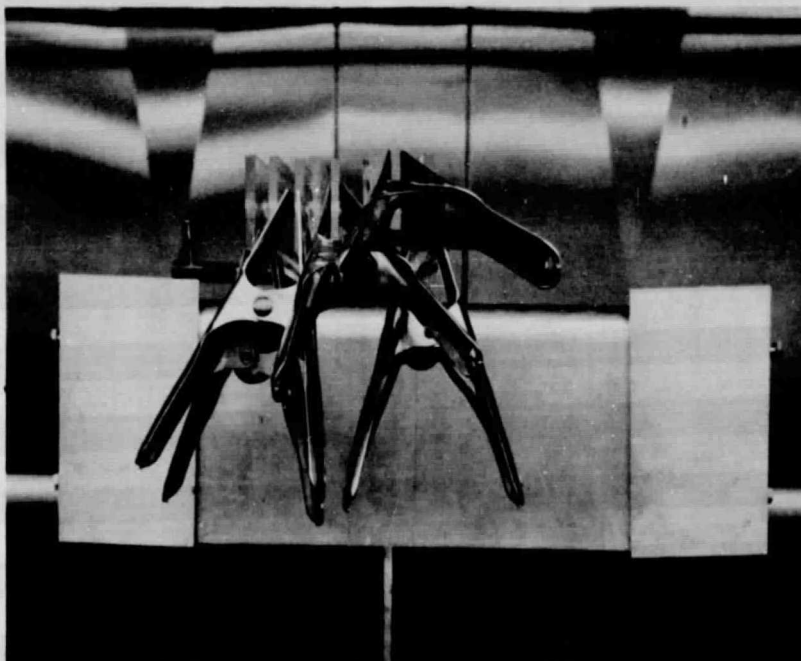


Photo 4. Strips on Fixture Ready to Form
into Light Guide Configuration

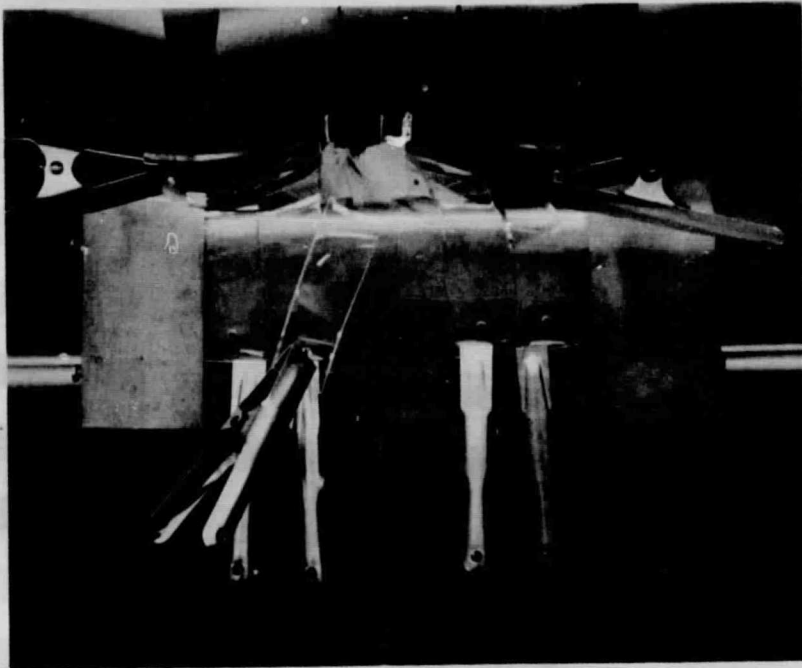


Photo 5. Strips Half-formed

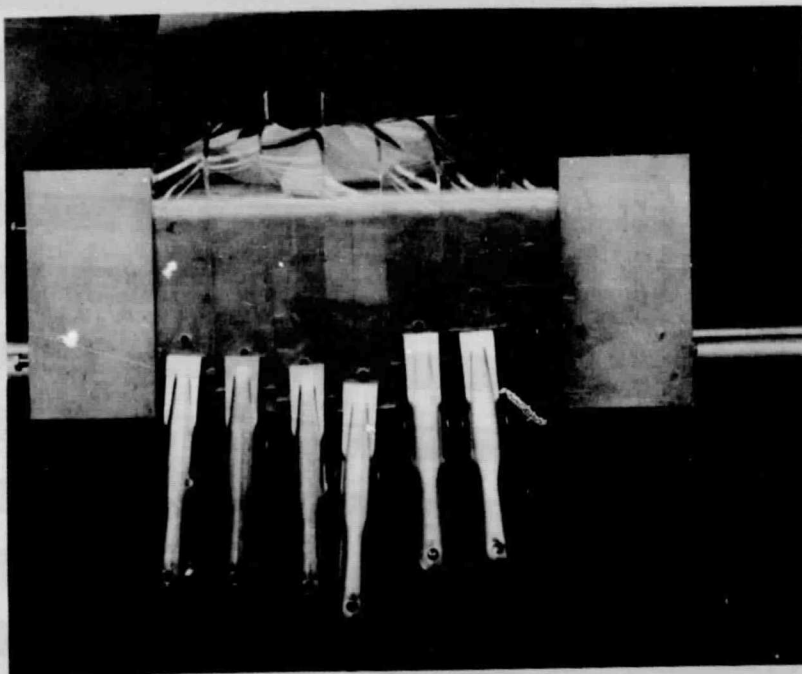


Photo 6. Strips Completely Formed

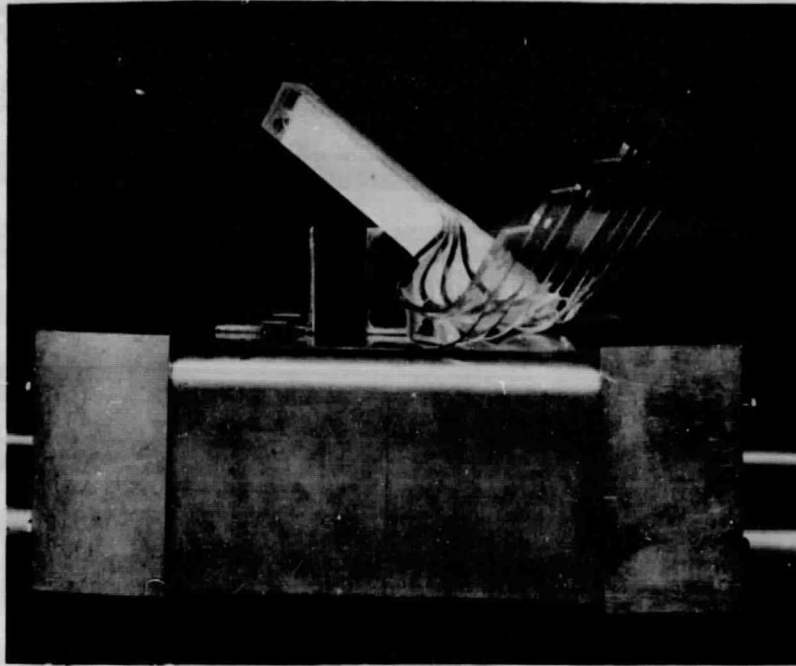


Photo 7. Light Guide Assembly Before Layoff
and Machining

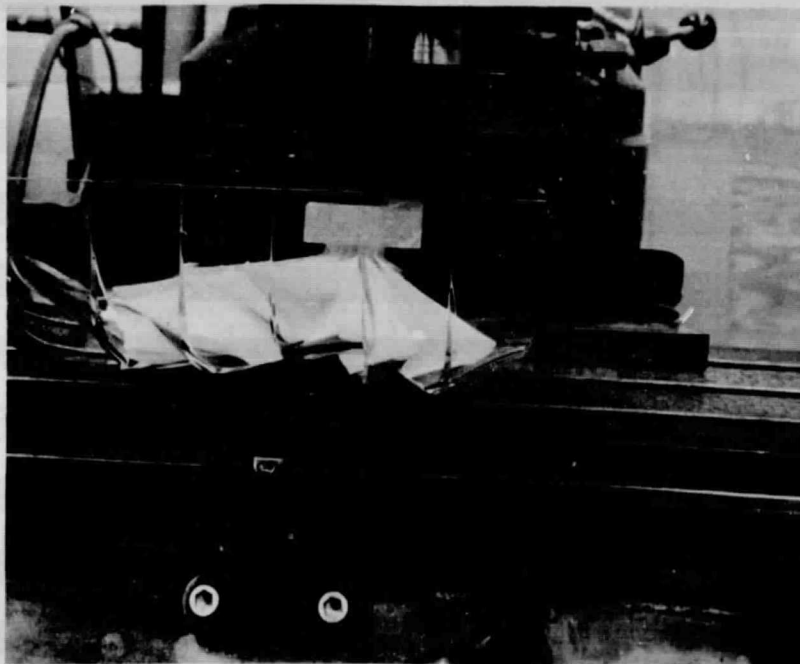


Photo 8. Machining Edges to Length

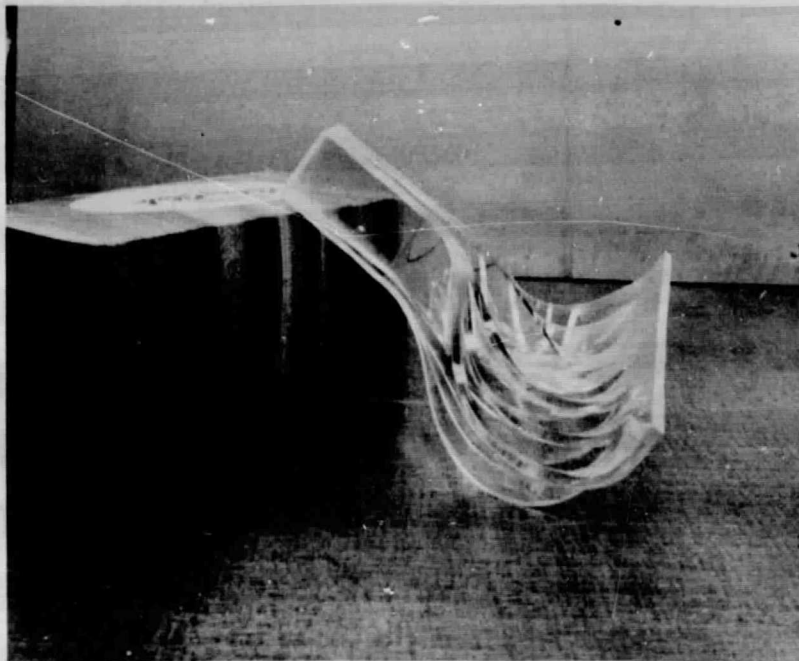


Photo 9. Finished Light Guide Assembly



Photo 10. Light Guide Bonded to Scintillator Tile

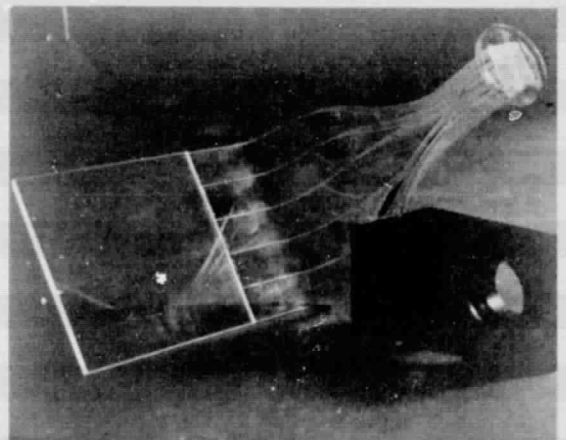
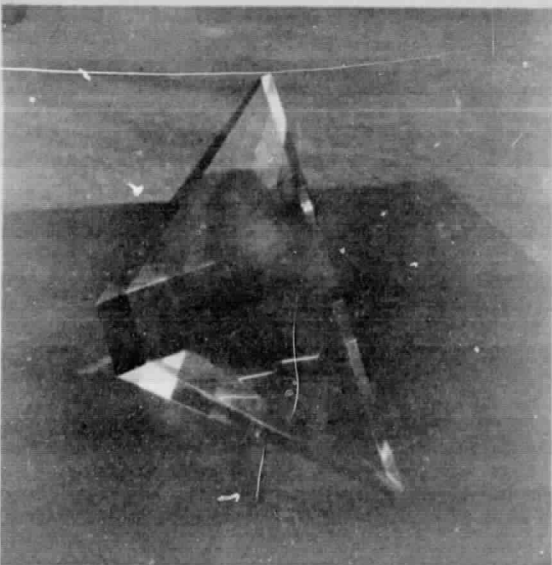
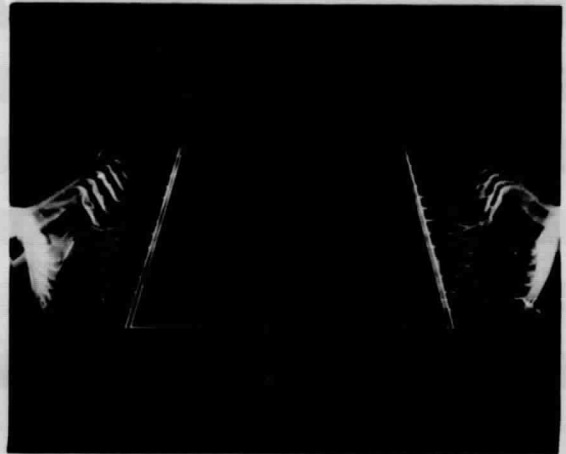
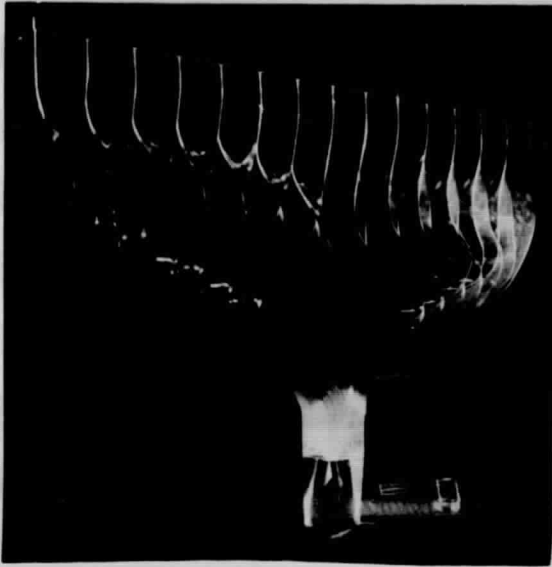


Photo 11. Typical Light Guide Configurations

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